

# Achieving And Sustaining Human Exploration of Mars

## The Fourth Community Workshop (AM IV)



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# *Why Community Affording, Achieving, and Sustaining Human Exploration of Mars workshops?*

About a half decade ago, several professionals working mainly in industry on scenarios for initial human exploration of Mars exploration together recognized that, under generally similar assumptions, there was a fair degree of similarity among these scenarios.

Moreover, opportunities should be sought for greater community input into NASA's own scenario-building for the future of human space flight.

A series of focused community workshops were considered to be effective to critically assess the increasingly sophisticated scenarios.

*Explore Mars, Inc.* & the *American Astronautical Society* agreed to support them.

Four workshops to date each involve about sixty professional scientists, engineers, technologists, and strategists from NASA, academia, aerospace corporations, the National Academies, consulting organizations, and potential international partners.

Each workshop produced a series of presentations and reports briefed to NASA leadership and other stakeholders and may be found at

<http://www.exploremars.org/> [AM IV is in advanced draft form.]

# Previous Three AM Community Workshops



## **AM I (December, 2013 at The George Washington University)**

Community-based critical assessment of the claimed affordability of several non-NASA scenarios for initial human missions to Mars.



## **AM II (October, 2014 at The Keck Institute, Pasadena)**

Community-based critical assessment of updated non-NASA scenarios for human exploration of Mars. Introduced priority science goals into scenarios.



## **AM III (December, 2015 at the Space Policy Institute, GWU)**

Integration of priority science goals with increasingly detailed human space flight scenarios: modify science goals and/or elements of human exploration, including planetary protection.



# Achieving & Sustaining Human Mars Exploration

December 2016 at DoubleTree Hotel, Monrovia



With substantial critically reviewed work supporting the contention that initial human missions to Mars by the mid-2030s was affordable, our workshop turned toward assessing achievability:  
What major goals (i.e., “long poles”) must be achieved – and how – before initial human missions.

# AM IV Workshop Participants

Molly Anderson (NASA HQ STMD)  
Anthony Antonelli (LM)  
John Baker (JPL)  
Deborah Bass (JPL)  
Dave Beaty (JPL)  
Katie Boggs (NASA HQ HEOMD)  
John Bradford (SpaceWorks Enterprises)  
Chris Carberry (Explore Mars)  
Joe Cassady (Aerojet Rocketdyne)  
Neil Cheatwood (LaRC)  
Timothy Chichan (LM)  
Sandy Coleman (Orbital ATK)  
John Connolly (JSC)  
Pan Conrad (GSFC)  
Mark Craig (NASA retiree)  
Rick Davis (NASA HQ SMD)  
Sydney Do (JPL)  
Leonard Dudzinski (NASA HQ)  
Matt Duggan (Boeing)  
Alicia Dwyer-Cianciolo (LaRC)  
Bret Drake (Aerospace Corp)  
Michael Elsperman (Boeing)  
Erin Flynn-Evans (ARC)  
Paul Fulford (MDA)  
Michael Fuller (Orbital ATK)  
Michele Gates (NASA HQ HEOMD)

Sam Gunderson (Blue Origin)  
Jeff Herath (LaRC)  
Lindsay Hays (JPL)  
Steve Hoffman (SAIC)  
Robert Howard (JSC)  
Jeff Johnson (APL)  
Wesley Johnson (NASA GRC)  
Steve Jolly (LM)  
Alan Jones (Orbital ATK)  
Russ Joyner (Aerojet Rocketdyne)  
Ave Kludze (NASA HQ)  
Daniel Levack (Aerojet Rocketdyne)  
Rob Manning (JPL)  
Lee Mason (GRC)  
Arman Mottaghi (UVa Student)  
Patrick McClure (LANL)  
Michael Meyer (NASA HQ SMD)  
Doug Ming (JSC)  
Paul Niles (JSC)  
Peter Norsk (JSC)  
Tara Polsgrove (MSFC)  
Maria Perino (Thales Alenia Space)  
Hoppy Price (JPL)  
Margaret Race (ARC)  
Michael Raftery (Explore Mars)

Kent Rominger (Orbital ATK)  
Michelle Rucker (JSC)  
Sarag Saikia (Purdue)  
Jerry Sanders (JSC)  
Graham Scott (NSBRI)  
Matthew Simon (LaRC)  
Dennis Stone (JSC)  
Nantel Suzuki (NASA HQ HEOMD)  
Harley Thronson (GSFC)  
Larry Trager (Aerojet Rocketdyne)  
Paul van Sustante (Mich Tech)  
Charles Whetsel (JPL/Caltech)  
Paul Wooster (SpaceX)  
Rick Zucker (Explore Mars)

*N.B.: Affiliations throughout this document are for identification purposes only. Findings and observations in this document are consensus and not intended to imply unanimity in all cases*



## Nine “Long Poles” Assessed at AM IV

- Mars System Reconnaissance (D. Beaty, C. Whetsel, *et alia*)
- Aggregation/Refueling/Resupply (R. Davis *et alia*)
- Transit Habitation and Laboratory (J. Baker *et alia*)
- Entry, Descent, and Landing (J. Cassady *et alia*)
- Surface Habitation and Laboratory (L. Hays, S. Hoffman, *et alia*)
- Surface Power (R. Zucker, L. Mason, *et alia*)
- Mars Ascent Vehicle (B. Drake, T. Polsgrove, *et alia*)
- Human Health/Biomedicine (P. Norsk, G. Scott, *et alia*)
- Sustainability (M. Craig *et alia*)

# Content of Each “Long Pole” Assessment

Major elements of the “long pole” (for a long-stay surface mission) and key characteristics:

- Basic description: “sub-poles,” key technologies/capabilities
- Why this is a “long pole” and why does this need to be developed
- Why this is challenging and why this is achievable (with substantive reasons: e.g., high TRL/SOA, advanced SOA, few or no “miracles” required, scheduled demonstration or precursor activities)

Development plan(s) or options, if any, to make this achievable:  
Milestones, investment strategy and priorities,

- Precursor and demonstration site(s), where is this being developed (US aerospace, NASA, academia, internationals)
- Time to close “long pole,” including “sub-poles” and related “long poles”
- Creative alternatives, if any, for accelerating closing

# MAJOR CONCLUSIONS (DRAFT v0.8)

The estimated length of time to retire the long poles strongly suggests that a human mission **to the surface of Mars** could be accomplished in the in early to mid-2030s with sufficient funding. *That is, engineering and technology is not the limiting factor.*

A human **orbital mission** to Mars does not require retiring as many long poles to be closed and could be attempted as early as 2026 or 2028. Such a mission would substantially inform subsequent missions.

Landing systems are the major long pole, requiring about 17 years to retire, although are not a pre-requisite for orbital missions.

Robotic reconnaissance over the next two decades is an essential element of preparing for human missions, as well as a source of priority science discoveries.

The role of logistics support, supply nodes, refueling and aggregation needs to be studies in more detail and could be enabling of sustained human missions.

There is significant interdependencies among the various habitation modules, transit and surface. The value of modularity needs to be assessed as a priority.

Surface power looks very promising with the advent of small nuclear fission reactors.

Operations with astronauts on the lunar surface were not identified as offering value to initial human missions to Mars.



# AM IV Long Pole 1. Mars System Reconnaissance in Advance of Astronaut Missions (I)

## The Long Pole

Certain datasets are needed to guide architecture and engineering design of a long-stay mission to the Martian surface, which require reconnaissance activities *at Mars*, specifically: Ground truth for resources, surface mapping, and linkage to orbital data; knowledge of atmospheric dynamics; surface dust environment; health considerations (toxicity, extant biological potential); mapping of special regions for potential “forward” planetary protection/contamination concerns; demonstration of proof-of-concept hardware systems (e.g., ISRU production) in the relevant environment interacting with indigenous materials.

## Major Elements of the Long Pole

- Biological, geochemical, and atmospheric reconnaissance to retire strategic knowledge gaps
- In-situ resource utilization, including
  - Reconnaissance to determine where minimally acceptable resources are located and their attributes*
  - Development of technology needed to use those resources*
- Reconnaissance to establish/optimize astronaut-enabled science program (now largely complete)
- Landing site selection

# AM IV Long Pole 1. Mars System Reconnaissance in Advance of Astronaut Missions (II)

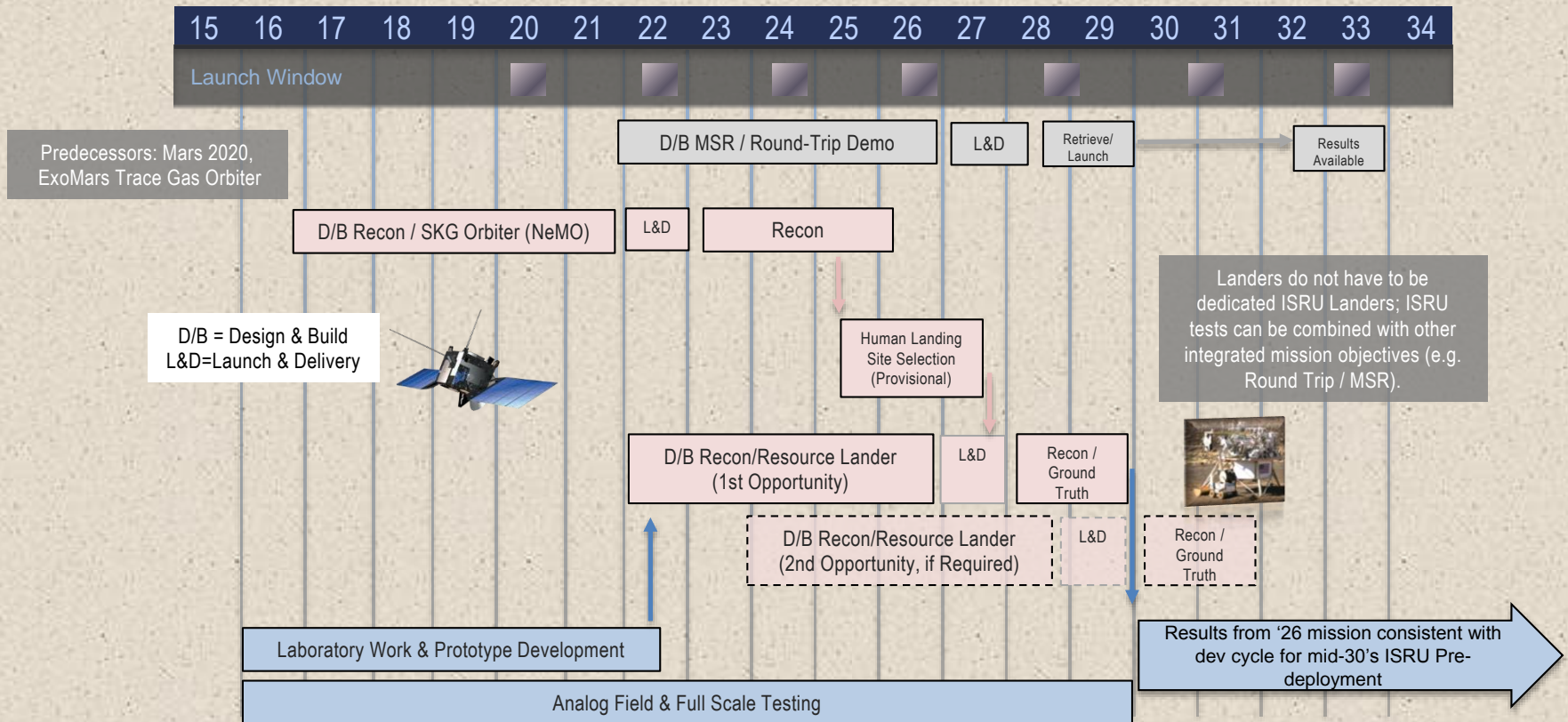
**Primary challenge to closing long pole:** Identify from orbit and characterize/demonstrate resource extraction feasibility from surface sites with adequate resource potential to support long-term sustained exploration operations.

**Secondary challenges to closing long pole:** (1) Demonstration of ISRU and off-Earth mining techniques and technologies. (2) Filling of other strategic knowledge gaps required to enable design of the crew landing and surface systems.

**Time to close long pole:** 10-12 years: 6-8 years for orbital asset to identify sites and 4-6 years for surface ground truth from robotic precursor from landing site. This assumes missions that enable analysis of returned samples, if needed (e.g. dust characteristics, toxicity, particle size distribution, etc.), occur in parallel over similar time frame.



# Mars System Reconnaissance & Supporting Engineering Developments



Length of recon periods is dependent on amount of data to be collected, data processing capabilities onboard the spacecraft and/or lander, other users of Deep Space Network as well as relay transmission rates back to Earth. SAR and high resolution stereoscopic imaging are heavy data generators





The background of the slide is a reproduction of the painting 'The Starry Night' by Vincent van Gogh. It features a turbulent, swirling night sky with a bright yellow sun or moon in the upper right corner. Numerous stars are depicted as glowing, circular motifs. In the foreground, dark, silhouetted cypresses stand on the left, and a small village with a prominent church spire is visible in the lower center. The overall style is characterized by visible, expressive brushstrokes.

**BACKUP**



# AM IV Ground Rules and Assumptions

- As presented and assessed at AM IV, there are a modest number ( $\sim 9$ ) of common elements among the handful of plausible scenarios for human Mars exploration.
- Early and focused technology investment, including precursors and demonstration missions, is essential for the timescale adopted here.
- Technical/engineering solutions exist for landing and long-duration operations on the martian surface.
- Partnerships (international, industrial, commercial, academic . . .) will be an essential component of human Mars exploration.
- Research and development will continue on ISS at least through the mid-2020s.
- SLS and Orion will be available during the time period considered here, so will not be assessed in depth in this workshop.
- The budgets for space agencies will be approximately flat at least for the next few years. Budget growth is possible in response to an international commitment to travel to Mars.